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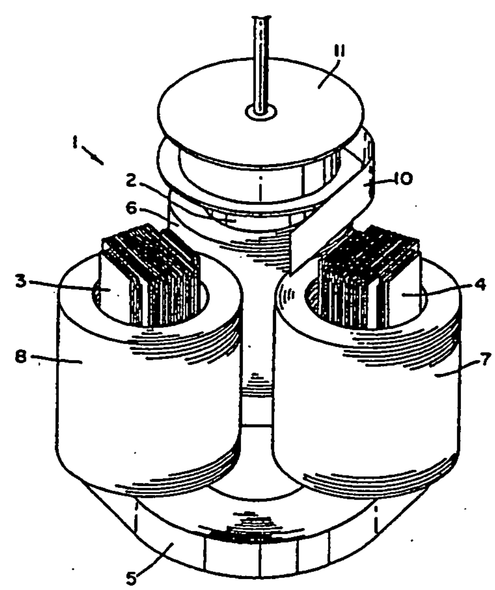
(54) **Improvements in or relating to electrical induction apparatus.**

(57) A magnetic core (1) for electrical induction apparatus, e.g. a power transformer or a distribution transformer, comprises spaced apart yokes (5, 9) each formed of wound magnetic strip material (10), e.g. amorphous magnetic material, and legs (2-4) interconnecting the yokes (5, 9). The legs (2-4) are formed of at least substantially planar layers of magnetic material and are interleaved at their ends with the wound yoke layers of magnetic strip material (10).



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Improvements in or relating to electrical induction apparatus

This invention relates to a magnetic core for induction apparatus, e.g. a power transformer or a distribution transformer, the magnetic core being of the kind comprising spaced apart yokes each formed of magnetic strip material and legs, interconnecting said yokes, each formed of layers of magnetic material which are substantially planar for at least most of their length and each being interleaved at its ends with yoke layers of said magnetic strip material. The invention also relates to a method of manufacturing, and to induction apparatus provided with, a magnetic core of the kind referred to.

A known magnetic core of the kind referred to for a three phase power transformer comprises a plurality of interleaved silicon steel plates assembled together to provide a laminated core having spaced apart, horizontal top and bottom yokes interconnected by three vertical legs. The laminations of the yokes and legs lie in substantially parallel planes. In order to position pre-wound electrical windings around the laminated vertical core legs, it is necessary firstly to remove the top yoke, secondly to position the electrical windings around the vertical legs and finally to replace the top yoke, typically a number of plates at a time.

Another known magnetic core of the kind referred to is described in DE-A-2160197 and comprises two spaced apart and generally toroidal yokes and three laminated legs mutually offset at an angle of 120°. Each toroidal yoke is constituted by a plurality of arcuate lengths of magnetic strip material, each approximately 2/3 of the average circumference of the yoke, which are assembled together in such a manner as to enable layers of each yoke to be interleaved with the laminations of the legs.

Such known magnetic cores of the kind referred to

can be made with extremely low magnetic losses. However the availability in recent years of low loss materials, such as "METGLAS" (Trade Mark) strip material manufactured by Allied Chemical Corporation, has led to the possibility of magnetic cores of even lower magnetic loss being produced.

Amorphous ferromagnetic materials are produced by the rapid solidification of molten metals at cooling rates of about one million degrees centigrade per second so that solidification occurs before the atoms have a chance to segregate or crystallize. To achieve this high quenching rate the finished material must be thin. In addition the material is very hard and difficult to cut. These properties render it difficult to produce conventional magnetic cores, of the kind referred to, where much cutting of strip material to produce the necessary laminations is required. However transformer cores have been produced from this low loss material by building up the core from wound layers of strip material. In particular a transformer core has been produced by winding low loss strip material into rectangular first and second coils, arranging the first and second coils back to back and winding further low loss strip material in a third coil around the first and second coils. In this way a central vertical core leg is formed by the back to back sides of the first and second coils and outer coil legs are formed by outer parts of the first and second coils and by parts of the encircling third coil. Spaced apart, horizontal upper and lower core yokes are formed by upper and lower parts, respectively, of the three wound coils.

However known transformer cores having yokes formed of wound low loss material have a number of disadvantages. Firstly it is difficult to position electrical windings around the vertical core legs since the core yokes cannot

be separated from the core. It is thus necessary either to wind electrical windings directly onto the core legs or to cut through the core yokes, position pre-wound electrical windings on the core legs and finally re-join the cut core yokes. Both of these methods are unsuited to the manufacture of magnetic cores for power transformers and can only be used in practice for the manufacture of magnetic cores for small distribution transformers. Secondly, the layers of the wound yokes are generally arranged perpendicular to the axes of the electrical windings on the vertical legs. With such an arrangement leakage flux from the electrical windings generates eddy currents in the yokes resulting in high temperatures and magnetic losses in the core.

The present invention aims to provide a magnetic core for induction apparatus having yokes formed of magnetic strip material in which the above-identified problems are avoided.

According to one aspect of the present invention a magnetic core for induction apparatus, the magnetic core being of the kind referred to, is characterised in that each yoke is formed of wound layers of the said magnetic strip material.

The legs may be formed from laminations of grain oriented magnetic material, e.g. silicon steel, and/or from layers of amorphous magnetic material typically formed by winding or folding one or more strips of the amorphous material backwards and forwards on itself to build up each multi-layered core leg.

Preferably each yoke is wound from one or more strips of amorphous magnetic material. The yokes may be wound into closed loops or coils of any desired shape although a closed loop of generally triangular shape with rounded

corners is preferred.

A typical construction of magnetic core for a three phase transformer comprises three vertical legs, e.g. laminated legs, spaced at intervals of 120 degrees about a central vertical axis and two horizontal yokes each wound in coil form from magnetic strip material. At the top and bottom of each leg, the leg layers or laminations are interleaved with the layers of the yokes.

According to another aspect of the present invention there is provided induction apparatus, e.g. a transformer, having a magnetic core according to said one aspect of the present invention.

According to a further aspect of the invention, a method of manufacturing a magnetic core for induction apparatus comprising forming legs from layers of magnetic material which are substantially planar for at least most of their length and arranging magnetic strip material at opposite ends of the legs so as to form two spaced apart yokes interconnected by the legs with layers of magnetic strip material of each yoke being interleaved with said layers of magnetic material of said legs at respective ends of said legs, is characterised in that the said magnetic strip material is wound to provide the yokes with said layers of said magnetic strip material.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a schematic perspective view showing a stage in the manufacture of a three phase transformer and in particular showing a partly formed magnetic core according to the invention,

Figure 2 is a schematic end view of the magnetic

core, when fully formed, shown in Figure 1 but with no electric windings shown around legs of the magnetic core,

Figure 3 is a schematic view showing one way in which layers of a yoke of the magnetic core shown in Figure 2 may be interleaved with layers at one end of a leg of the magnetic core,

Figure 4 is a schematic view showing how ferromagnetic strip material may be folded to produce a layered core leg, and

Figures 5 and 6 show alternative constructions for interleaving the layers of a core yoke with the layers of a core leg.

Figure 1 shows a partly constructed three phase power transformer comprising a magnetic core generally designated 1, having three upstanding legs 2-4 and a lower yoke 5, and pre-formed cylindrical electrical windings 6-8, each of generally cylindrical shape, surrounding the limbs 2-4, respectively. In Figure 1 an upper yoke 9 (see Figure 2) is in the process of being formed by winding ferromagnetic strip material 10 from a roll 11. The yokes 5, 9 magnetically couple respective ends of the legs 2-4 and are generally of triangular form with rounded corners.

The core legs 2-4 are equally angularly spaced apart around a central axis 12 and are each formed of laminae stamped from conventional silicon steel. The laminae of each core leg 2-4 are staggered, or have two different lengths, so that when the laminae are placed against each other a plurality of slots 13 is formed at each end of each leg 2-4 (see Figure 3).

Each core yoke 5 (9) is formed by winding ribbons, of two different widths, of amorphous ferromagnetic mater-

ial, e.g. "METGLAS" strip material, into a coil with the layers of ribbons forming each yoke extending widthwise in substantially the same direction as the central axis 12. By winding several turns of one ribbon alternately with several turns of a different width ribbon, each yoke 5 (9) is provided with continuous grooves or slots 15 in an end surface facing towards the other yoke. A similar construction may be formed by winding a number of rolls of ribbon of one width in one or more turns alternately with a number of rolls of ribbon of another width in one or more turns. As can be seen with reference to the upper core yoke 5 shown in Figure 3, each yoke comprises yoke parts 5a wound from ribbon of one width and yoke parts 5b wound from ribbon of a larger width. The yoke parts 5a are spaced from each other by the yoke parts 5b by substantially the thickness of the laminae making up the core legs 2-4. Since the core leg laminae are generally thicker than the ribbons of amorphous ferromagnetic material, it is necessary for each yoke part 5a, 5b to be formed of several turns or layers of its respective ribbon.

By forming the legs 2-4 and yokes 5, 9 in the manner described above, the finished core is assembled by interleaving layers of each yoke with layers of the respective leg ends. Thus, as shown in Figure 3, the slot-defining yoke parts 5b are inserted into the slots 13 defined between the laminae of the legs 2 (3,4).

The magnetic core 1 described above has particularly low magnetic loss and is ideal for use in a low loss transformer. In particular the yokes 5, 9 are made of wound layers of low loss amorphous ferromagnetic material. By winding yoke layers in continuous turns a yoke can be formed in a relatively simple manner, requiring comparatively little cutting of the strip material. The wound yoke layers are arranged on edge to the electrical

windings 6-8 (i.e. the yoke layers extend widthwise substantially in the same direction as the central axis 12) so that the generation of eddy currents in the yoke layers caused by magnetic leakage flux is minimised, resulting in magnetic losses and the generation of heat in the yokes also being minimised. The interleaving of layers of each core yoke with respective ends of the core legs ensures that there is good magnetic coupling between the various core parts. The formation of each yoke as a closed loop or coil is designed to minimise the length of flux path from one core leg to the other two core legs.

In other embodiments of the invention, it is possible to form the core legs 2-4 from laminae of the same length, the layers of ferromagnetic material being interleaved between respective ends of the core leg laminations. In this case each leg lamination may be slightly distorted out of a planar condition at each of its ends although the laminations will be substantially planar throughout the greater part of their lengths. Slots 15 do not now need to be formed in the yokes 5, 9. The thickness of the interleaved leg and yoke layers will, in this instance, be greater than portions of the core and yoke which are not interleaved. Alternatively the core legs 2-4, instead of being formed of laminations may be formed wholly or partially of pliant strip material, e.g. ribbons of amorphous ferromagnetic material. Figure 4 illustrates one way in which a ribbon of amorphous ferromagnetic material is folded or wound backwards and forwards on itself to produce a multi-layered core leg 21. By using an indexing spigot 22, the length of each folded layer may be controlled to provide slots 23 at opposite ends of the core leg for coupling the latter to end yokes.

Figures 5 and 6 show schematically alternative methods of interleaving ferromagnetic layers of a core leg with ferromagnetic layers of a core yoke. In Figure

5 a ribbon 30 of amorphous ferromagnetic material is folded in the manner described with reference to Figure 4 to produce a multi-layered core leg 31 having slots 32 at each of its ends (only one of which is visible in Figure 5). A further ribbon 33 of amorphous ferromagnetic material having a width corresponding substantially to the depth of the slots 32 is then wound into the slots 32 to form one or both multi-layered end yokes 34.

Instead of folding ribbons of amorphous ferromagnetic material into layers of different lengths to provide slots in the ends of the core legs, it is possible to form each core leg from equal length folded layers of ribbon 40 (see Figure 6) and to subsequently separate the folded layers at each end of the core leg to provide slots 41 therein. With such a construction the layers of ribbon 40 are substantially planar throughout most of their length, although the end portions of the layers may be slightly out of a planar condition. As in the manner described with reference to Figure 5, each multi-layered end yoke is then formed by winding a further ribbon 42 of amorphous ferromagnetic material into the slots 41.

Although it is preferred to form the yokes 5, 9 from ribbons or strips of amorphous ferromagnetic material, the yokes may be formed from other types of ferromagnetic strip material.

It should also be appreciated that it is not essential to form each yoke from strip material wound upon itself in turns. In particular a yoke of closed loop form may be constructed by connecting together two or more yoke parts end to end to form a closed loop yoke. In such a construction each yoke part may comprise layers of strip material folded backwards and forwards on each other to form the desired multi-layered yoke part, the yoke layers extending widthwise in substantially the

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same direction as the central axis 12. The layers at the ends of the connected-together yoke parts may be interleaved with each other to improve the magnetic coupling between the connected together yoke parts. Instead of the yoke parts being connected end-to-end to form a yoke of closed loop form, it is possible for three yoke parts to interconnect respective ends of the three spaced apart limbs or legs.

It will be appreciated that each of the magnetic cores described herein makes use of flexible magnetic strip material which is wound to form spaced apart core yokes, the layers of the wound flexible magnetic strip material being interleaved with layers of strip material forming the legs of the magnetic core. These layered core legs may themselves be made of flexible strip material or, alternatively, comprise conventional laminations - e.g stamped from thicker ferromagnetic sheet material.

Finally it should be stressed that all the drawings are schematic and that the relative dimensions of the core parts are not to scale. With regard to Figures 4 - 6, it will be appreciated that the slots 23, 32 or 42 may be formed by winding several "long" length layers and then several "short" length layers and so on instead of forming alternate "long" and "short" length layers. In addition Figures 5 and 6 are intended to show continuous layers of flexible strip material (33) passing through the slots 32, 41 to build up the wound yokes.

CLAIMS

1. A magnetic core (1) for induction apparatus comprising spaced apart yokes (5, 9) each formed of magnetic strip material (10) and legs (2-4), interconnecting said yokes (5, 9) each formed of layers of magnetic material which are substantially planar for at least most of their length and each being interleaved at its ends with yoke layers of said magnetic strip material, characterised in that each yoke (5, 9) is formed of wound layers of the said magnetic strip material (10).

2. A magnetic core according to claim 1, characterised in that each leg (2-4) comprises laminations of grain oriented magnetic material.

3. A magnetic core according to claim 1 or 2, characterised in that each leg (2-4) comprises layers of amorphous magnetic material.

4. A magnetic core according to claim 3, characterised in that the layers of amorphous magnetic material of each leg (2-4) are formed by winding or folding one or more strips (30) of the amorphous material backwards and forwards on itself to build up each multi-layered core leg.

5. A magnetic core according to any of claims 1 to 4, characterised in that each yoke (5, 9) is wound from one or more strips (10) of amorphous magnetic material.

6. A magnetic core according to any of claims 1 to 5, characterised in that each yoke (5, 9) is wound into a closed loop or coil.

7. A magnetic core according to claim 6, characterised in that each yoke (5, 9) is wound into a closed loop

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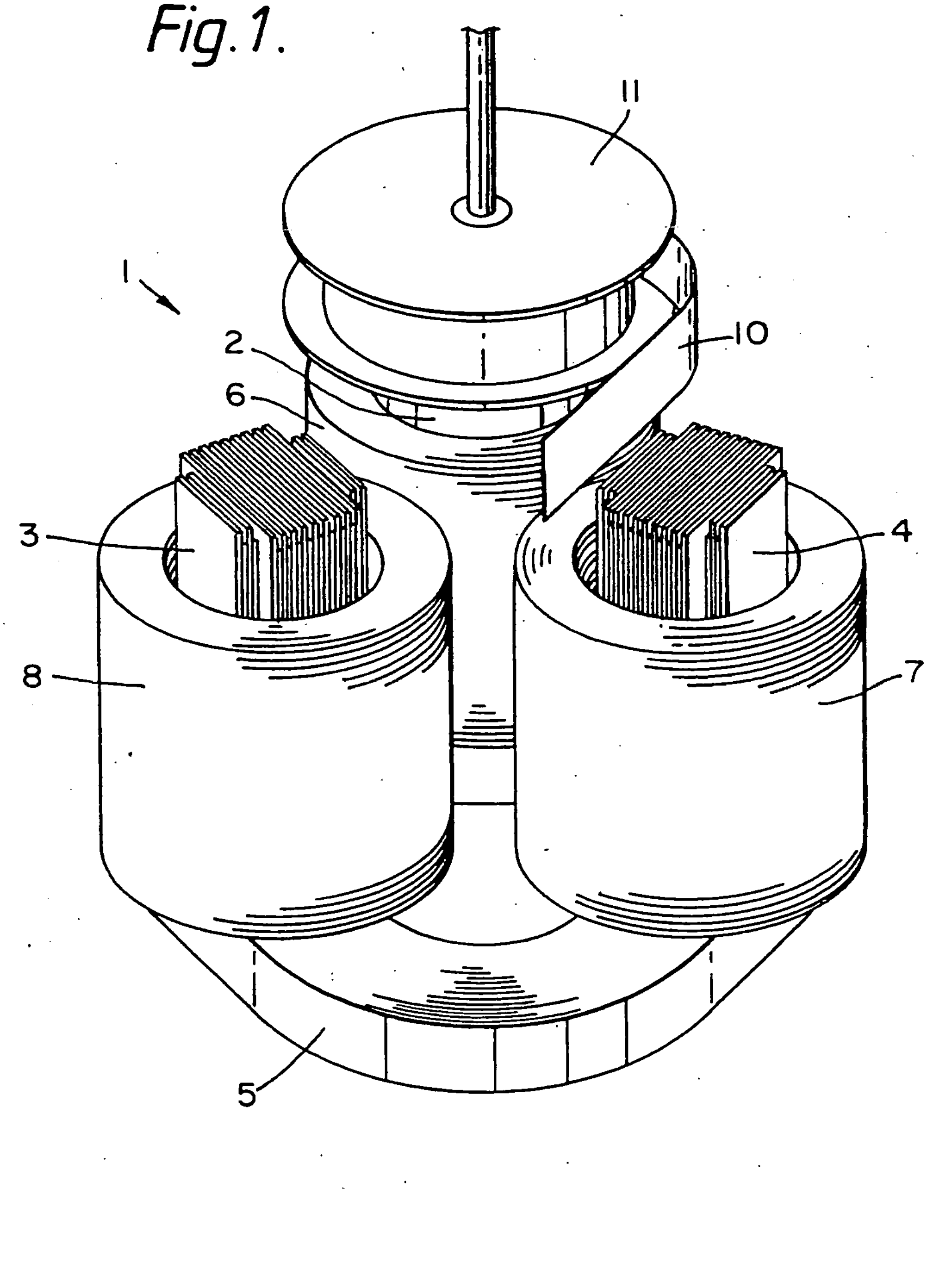
of generally triangular shape with rounded corners.

8. A magnetic core according to any of claims 1 to 7 and designed for a three phase transformer, characterised in that three vertical core legs (2-4) are provided which are spaced at intervals of 120° about a central vertical axis (12) and in that two horizontal yokes (5, 9) are provided which are wound in coil form from magnetic strip material (10).

9. Induction apparatus characterised in that it is provided with a magnetic core (1) according to any of the preceding claims.

10. A method of manufacturing a magnetic core (1) for induction apparatus comprising forming legs (2-4) from layers of magnetic material which are substantially planar for at least most of their length and arranging magnetic strip material (10) at opposite ends of the legs (2-4) so as to form two spaced apart yokes (5, 9) interconnected by the legs (2-4) with layers of magnetic strip material of each yoke being interleaved with said layers of magnetic material of said legs (2-4) at respective ends of said legs, characterised in that the said magnetic strip material (10) is wound to provide the yokes (5, 9) with said layers of said magnetic strip material (10).

Fig.1.



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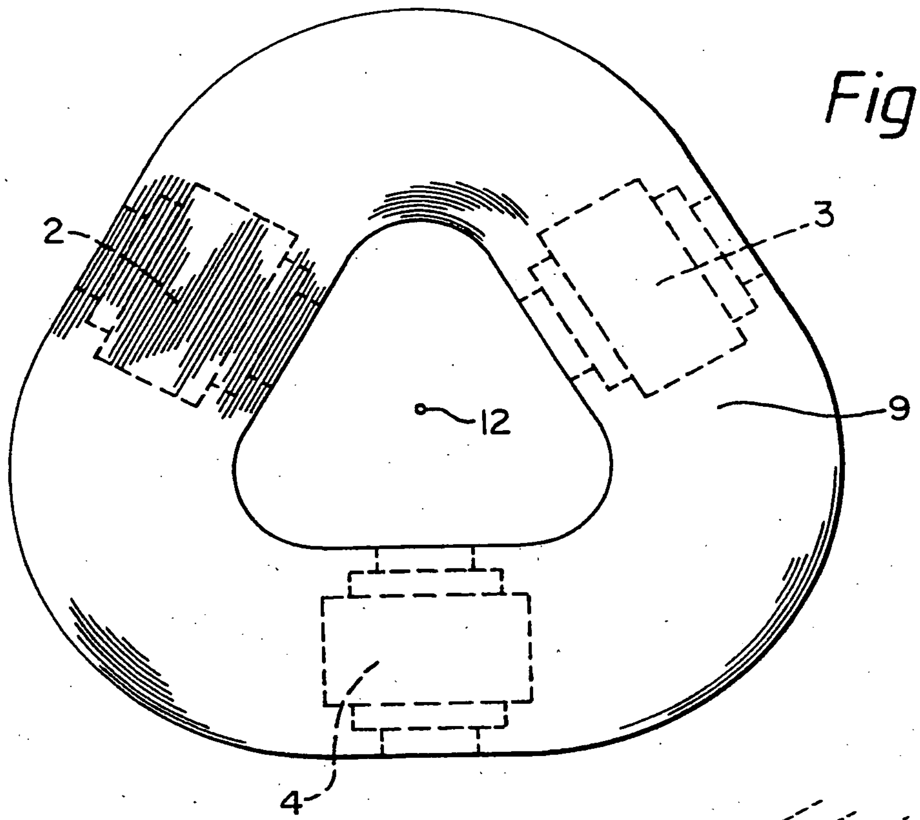


Fig. 2.

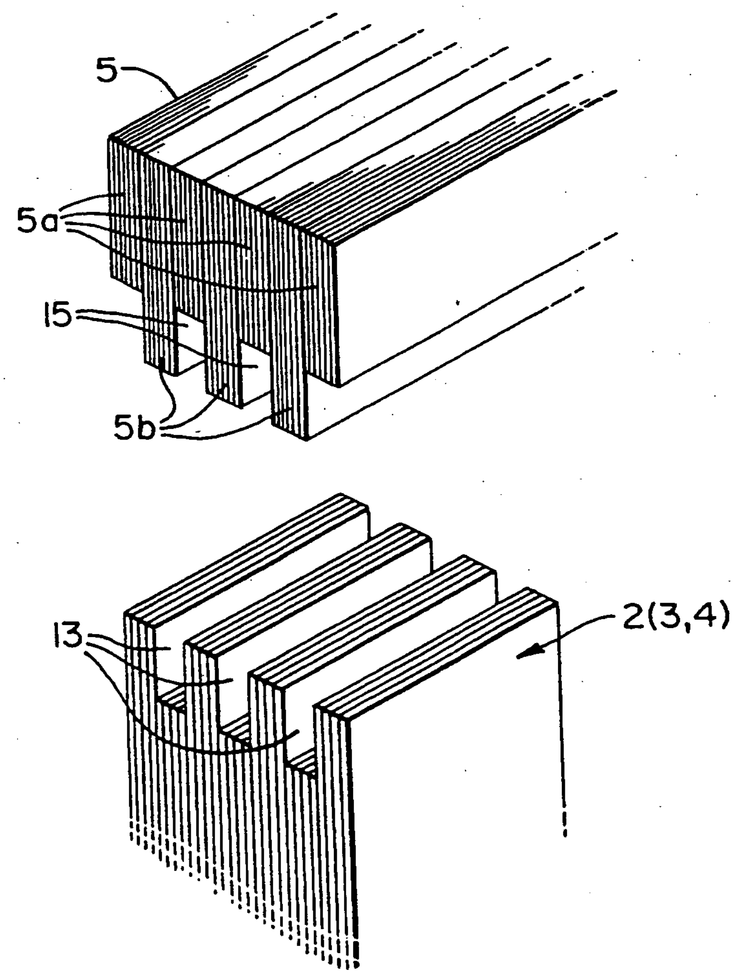


Fig. 3.

Fig.4.

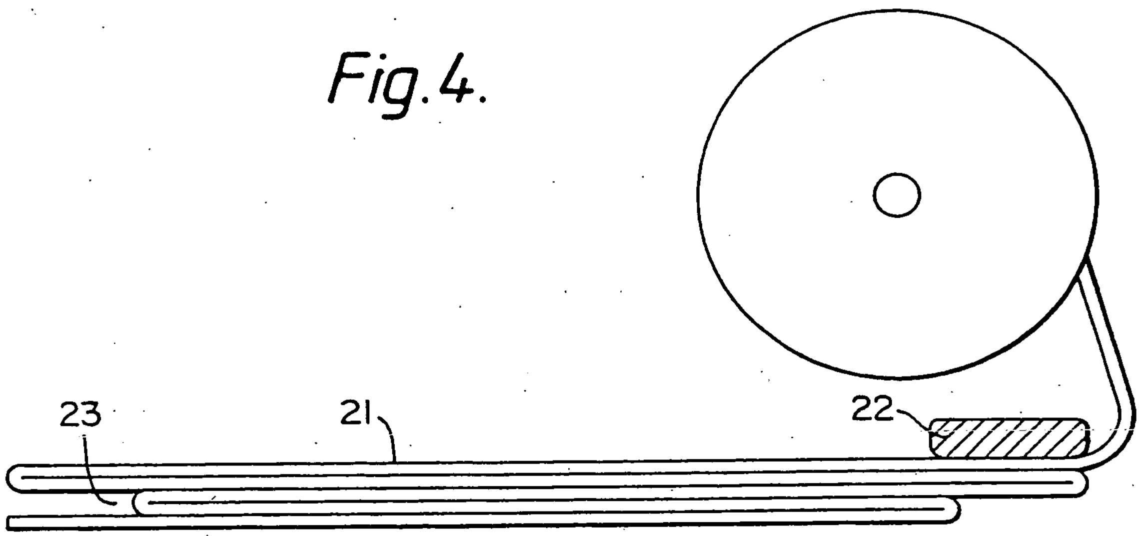


Fig.5.

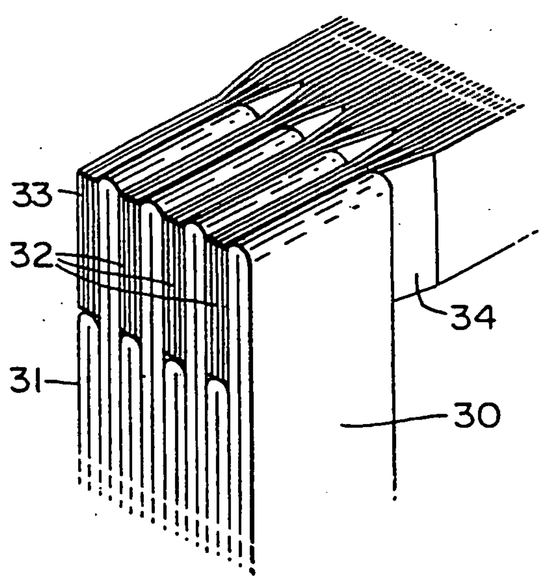
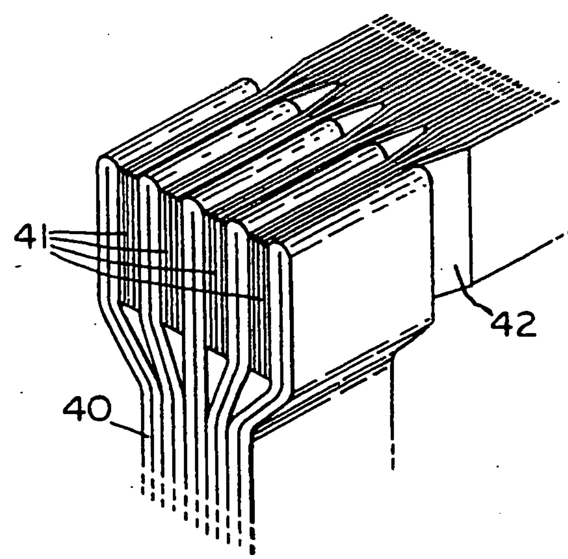


Fig.6.



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EUROPEAN SEARCH REPORT

0151048

Application number

EP 85300695.5

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
	AT - B - 219 705 (BBW)		H 01 F 27/24 H 01 F 41/02
X	* Page 1, lines 14-36; fig. 1-5 *	1,6-9	
Y	* Page 1, line 37 - page 2, line 4; fig. 6,7 *	2-5,10	
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Y	DE - B - 1 247 468 (SIEMENS) * Column 3, lines 46-60; fig. 1 *	2	
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Y	US - A - 4 364 020 (LIN) * Column 3, line 57 - column 4, line 5; fig. 3,4 *	3	
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Y	US - A - 4 085 603 (VANEK) * Column 3, lines 5-38; fig. 1,2 *	4,5	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
	--		H 10 F 3/00 H 01 F 27/00 H 01 F 41/00
Y	AT - B - 204 634 (AG BBC) * Totality *	10	
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A	DE - A - 1 489 628 (AG BBC) * Page 3, paragraph 3 - page 4, paragraph 1; fig. 1 *	1,6,9	
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D,A	DE - A - 2 160 197 (HEITMEIER) * Claim 1; page 1, paragraph 4 - page 2, paragraph 2; fig. 1 *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	19-04-1985	PIRKER

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document f the same category
A : technological background
O : non-written disclosure
P : intermediate document
T : theory or principle underlying the invention
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